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Yield and growth characteristics for cotton under various irrigation regimes on sandy soil

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ABSTRACT

Over-watering cotton wastes a valuable and scarce resource; it can also lead to rank growth, nutrient leaching, and contaminated groundwater. Since under-watering can decrease yields, the question becomes one of finding the optimum application regime. An irrigation experiment was set up to apply water at six different application rates, ranging from 33% to 144% of normal, with hopes of identifying the regime that produces maximum yield. Two cultivars, Acala Maxxa and Acala PhytoGen-72 (*Gossypium hirsutum* L.), were planted on sandy soil and irrigated daily with a highly efficient subsurface drip irrigation system for four seasons. The results showed that on the average there was no significant difference in the yield of the two cultivars and there was no significant difference in the yield for the three wettest treatments. The driest of the three wettest treatments, treatment 4, was a critical point on the water production function curve. It represented the least amount of water applied that still produced essentially maximum yield, and it had the highest water use efficiency. This critical level of water application during mid-season was found to be, on the average, 95% of Class A pan evaporation; it corresponded to a total seasonal application of 654 mm of water. Any application less than this critical level decreased yields. Reducing the water application by 5% below the critical level caused about a 4.6% reduction in yield. The critical level produced a soil moisture level that remained nearly constant throughout the season. The final plant height was closely related to the depth of water applied, with the wettest treatment producing plant heights of 2.0 m, and the driest treatment producing plant heights of 0.6 m. At the extremes of the water application rates there were some small differences in the early-season growth rate of the plants, but the main cause of differences in final plant height was the date of cutout (cessation of main stem node production). The length of season for the driest treatment was about 4 weeks shorter than for the wettest treatment on both cultivars. Results showed that deficit irrigation of cotton on sandy soil can greatly reduce yield, and the practice should probably be avoided.

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1. Introduction

Irrigation water is becoming increasingly scarce and expensive, and it is important not to waste it. Over-irrigation of cotton can lead to excessive vegetative growth and it can also cause leaching of nutrients out of the root zone, increasing fertilizer costs and contaminating groundwater supplies. There is a greater chance for water losses on sandier soils. On the other hand, insufficient water application can lead to moisture-stressed plants with a reduced number of fruiting positions, fruit loss and poor boll development. The optimum level of water application is somewhere in the

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middle and is especially important to know on this sandy soil.

Data showing the relationship between yields and water application to cotton can be found as far back as 1934 (Crowther, 1934). Economists have given the yield–water relationship the name water production function (Hexem and Heady, 1978). A normalized general relationship for yield and water use is given in Doorenbos and Kassam (1979) for 16 different crops including cotton. From 12 years of drip irrigation experiments with cotton in Texas, using a wide range of water applications, Wanjura et al. (2002) found that maximum lint yield was produced with 740 mm of water, but from the regression equation for the data, a 20% deviation in this application depth reduced yield by only 2.6%. Ertek and Kanber (2003), using three application rates and two irrigation frequencies on cotton with drip irrigation, found that in one season there was no significant difference in yield among crop–pan coefficients (K_p) of 0.75, 0.90, and 1.05 for a screened evaporation pan; in a lower-yielding season the treatment with a $K_p = 0.75$ produced significantly lower yields than the wettest treatment. For two seasons, Dagdelen et al. (2006) applied water at five different rates (full irrigation and four deficit rates) to cotton. The total depth of water applied ranged from 257 mm to 867 mm, with the highest application producing the highest yield. Falkenberg et al. (2007) used three levels of water application rates and found no yield reduction in cotton with the deficit treatment of 75% of ET_c, an ET based on the Penman–Monteith equation and locally determined values for the crop coefficient. Several references show that cotton yields can actually be reduced by application of excessive water (Letey and Dinar, 1986; Grimes, 1994; Grimes et al., 1969; Jackson and Tilt, 1968; Karam et al., 2006; Wanjura et al., 2002). This study was conducted to determine the effects of various irrigation regimes on yield and growth characteristics of cotton grown on a sandy soil in the San Joaquin Valley of California, USA.

2. Materials and methods

2.1. *Location, soil and climate*

The research was conducted at the Shafter Research and Extension Center, Shafter, California, USA, on a fairly uniform sandy loam soil (coarse-loamy, mixed, non-acid, thermic Typic Torriorthents) typical of the eastern side of the San Joaquin Valley of California, at 35°31′N, 119°17′W. The elevation is 109 m above sea level, and the average annual rainfall is 167 mm, with little rain from May through September. A 0.8-ha field was set up to determine the optimum level of water application to Acala Maxxa and Acala PhytoGen-72 cotton (*Gossypium hirsutum* L.), using subsurface drip irrigation.

2.2. *Treatments, experimental design, and irrigation applications*

The plot layout is shown in Fig. 1 where each of the six circuits shown is a treatment. Each of the plots consisted of eight rows, 100 m long, with a spacing of 0.76 m between rows. In the year 2002, Acala Maxxa was planted in the northwest and southeast quarters of the field, and Acala PhytoGen-72 was planted in the northeast and southwest quarters. The next year, 2003, the locations were interchanged. This alternation continued in 2004 and 2006. The dashed lines are the location of walkways. A dripper line was buried 26 cm below the soil surface under every plant row, running the full length of the field. The dripper lines were of the tape type (TSX-710-30-340, from T-Tape, San Diego, CA), with 10-mil (0.25 mm) wall thickness and high-flow emitter outlets every 30 cm. The average operating pressure was 60 kPa and the average emitter discharge was 19 mL/min. Each of the six circuits at the control center fed 16 dripper lines and carried 98 L/min. Water was applied once a day, using manually adjusted time clocks as controllers, and watering began on about day of year (DOY) 135 and ended on about DOY 243. The field was level in all directions, and system pressures did not vary more than 4 kPa through out the field. To control nematodes, which are prevalent in the sandier phases of these soils, the field was fumigated with 190 L/ha of metam sodium 1 month prior to planting each year except in 2006, when it was thought that the crop rotation might be an adequate substitute for the fumigation. The only fertilizer applied was nitrogen, in the form of liquid urea, which from mid-May to the first week in August, was injected continuously into the supply water using small adjustable diaphragm-type pumps, one pump for each circuit. Each injection pump was calibrated to supply the same amount of nitrogen to each treatment during that time period, with a total nitrogen application of about 135 kg/ha. The planting dates were 23 April 2002, 5 May 2003, 29 April 2004, and 27 April 2006, and the final plant population ranged from 100,000 to 140,000 plants/ha.

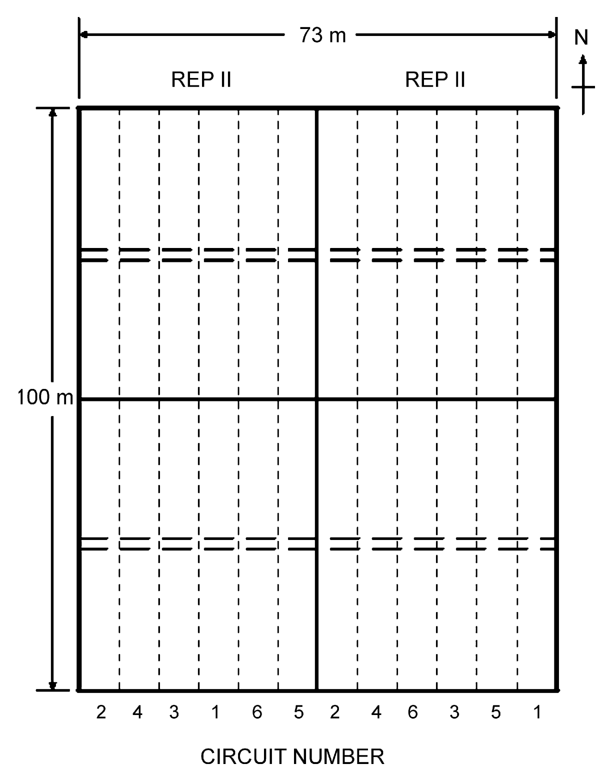

Fig. 1 – Plot plan. The circuit number is the same as the treatment number during the first year.

The depth of water application to each of the six treatments was governed by the equation:

$$I = F_t C_n E_{pan} \tag{1}$$

which is a slight variation on the procedure used in DeTar (2004), where I is the depth of water to apply (mm/day), E_{pan} the long-term average for Class A pan evaporation (mm/day), C_n the degree of ground cover (decimal fraction of the field area that would be shaded if the sun were directly overhead. It is equal to W_p/W_r, where W_p is the average width of the plant canopy, in cm, and W_r is the row spacing, in cm), and F_t is a variable representing a multiplier used to provide a large range of treatment effects, with values of 0.3, 0.5, 0.7, 0.9, 1.1, 1.3 for treatment numbers 1, 2, 3, 4, 5, and 6, respectively. In 2002 the treatment number and location were the same as the circuit number shown in Fig. 1. In each subsequent year the treatments were re-randomized among the circuits. The experimental design can be summarized as a split plot, randomized complete block, with two replications in the field and four replications over time. The main treatment was variety and the subplot treatments were the six different levels of water application.

The time clocks, which were adjusted twice a week, were set by using Eq. (1), with the C_n term calculated by forward extrapolation of the ground cover vs. time curve. Ground cover was measured weekly by dividing the average width of the plant canopy by the row spacing, as was done in Maas (1998), Wiegand et al. (1991), and DeTar and Penner (2007). The moisture in the soil profile was measured weekly with a neutron probe. One access tube for the neutron probe was located near the center of each subplot for a total of 24 tubes. The access tubes were 50 mm in diameter, 1.8 m long, and made of an aluminum alloy. Readings were taken at intervals of 0.3 m.

3. Results and discussion

3.1. The weather and potential ET during the four seasons

The growing season in the San Joaquin Valley in 2002 was nearly ideal for cotton production, with no extreme weather conditions and few insect problems, and as a result record yields were reported. Our plots were planted a little late, but nevertheless produced very good yields. In 2003 however, cold and wet planting conditions delayed planting everywhere, and ours was planted 3 weeks late. In spite of this, yields in the region, and also in our plots, were about average, probably due to low insect pressure again. In 2004 planting was 2 weeks late, there was some aphid pressure in July, and yields were below that of the region. Because of the low yield in 2004, the field was rotated out of cotton and into CB46 cowpeas for 2005. The year 2006 started out cold and wet; planting was 2 weeks late; then we had extremely hot weather in July, with 6 consecutive days of air temperatures exceeding 40 °C, causing considerable damage to squares and young bolls. The potential evapotranspiration (ET) for each month during the growing season is shown in Table 1 in the form of the average daily pan evaporation; the 4-year average for each month is also given.

Table 1 – Average pan evaporation (mm/day)

	2002	2003	2004	2006	Average
May	7.32	7.04	7.93	7.29	7.40
June	8.12	8.61	8.43	7.90	8.27
July	7.86	7.64	8.46	7.49	7.86
August	6.56	7.27	7.72	7.01	7.14
Average	7.47	7.64	8.14	7.42	7.67

The potential ET for August 2002 was 8.1% below the average, but none of the other monthly values in 2002 and 2003 varied more than 5% from the average. In 2004, the potential ET was very high, more than 7% above average for 3 of the 4 months. The potential ET in 2006 was consistently low, but not by more than 5%.

3.2. Efficiency of the irrigation system

The system was installed in early 1996. The distribution uniformity (DU) was measured in 2000 and again in 2005. The emitter discharge rate was measured for one random location in each of the 24 subplots. DU is defined as the average of the lowest quarter in the ranking divided by the average of all the data, which in this case was 0.95 for 2000 and 0.96 for 2005, both to be considered excellent. According to Wu (1995), when this kind of DU is combined with a slight deficit irrigation, the system efficiency can approach 100%. So we did indeed have a highly efficient irrigation system.

3.3. The water–yield relationships

In 2002 there was a definite maximum yield point in the water production function for PhytoGen-72 at treatment 4, as can be seen in Table 2. Treatment 6 produced a yield that was 22.7% lower than in treatment 4. For the Maxxa, in Table 2, this over-watering effect resulted in only a 4.2% reduction in yield. In the other 3 years, the over-watering effect is not strong or non-existent in either variety. Yields declined over the years. In 2003 and 2004, the yield for treatment 4 in the Maxxa was considerably lower than that in treatment 6, by 16.4% and

Table 2 – Lint yields for Acala cotton (kg/ha)

Variety	Year	Treatment numbers					
		1	2	3	4	5	6
PhytoGen-72	2002	644	896	1741	1999	1813	1545
PhytoGen-72	2003	443	834	1142	1412	1514	1491
PhytoGen-72	2004	275	757	1108	1334	1365	1467
PhytoGen-72	2006	175	455	729	1156	1168	1240
Average		385	736	1180	1475	1465	1436
S.E.		205	195	418	365	272	135
Maxxa	2002	541	790	1448	1883	1872	1803
Maxxa	2003	590	783	1078	1267	1493	1515
Maxxa	2004	301	697	936	1245	1343	1466
Maxxa	2006	323	536	794	1164	1302	1159
Average		438	702	1064	1390	1503	1486
S.E.		148	118	281	332	260	264

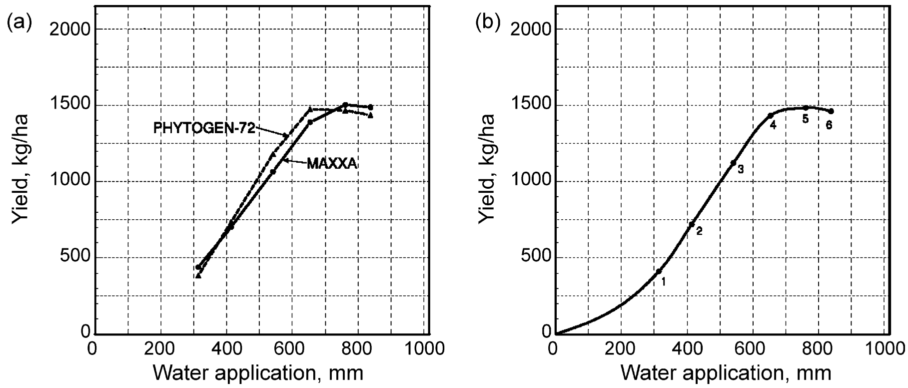

Fig. 2 – Four-year average lint yield as a function of total depth of water applied: (a) the two varieties separately; (b) the overall average of the two varieties combined, and the data is smoothed with a spline function. The change in the soil moisture status from before planting to after harvest is included in the depth of water application. Treatment numbers are shown in (b).

15.1%, respectively. By comparison, the yield for treatment 4 in the PhytoGen-72 was only 6.7% and 9.1% less than the maximum (treatment 5 in 2003, and treatment 6 in 2004).

In Fig. 2a, which is the 4-year average yield plotted against the average depth of water application, PhytoGen-72 appears to produce a peak yield with less water than Maxxa. However, the difference between the two varieties is not statistically significant; so the data were merged and then smoothed with a spline function; the results are shown in Fig. 2b. The *x*-axis for these plots comes from Table 3 and is the average for the total seasonal depth of water applied for each treatment, and includes the change in the soil inventory for the time period from before planting to after harvest. Analysis of variance (ANOVA) for the yield data shown in Table 2 produced a Fisher $F = 0.35$ and no significant difference in yield due to variety at the 5% level of confidence, and there was no significant interaction between the two varieties with Fisher $F = 0.67$. The ANOVA showed that the LSD_{05} for yield in the irrigation treatments was 129 kg/ha and that there was no significant difference at 5% for the yield of the three wettest treatments (treatments 4, 5, and 6). There were large differences among treatments 1, 2, 3, and 4 with a Fisher $F = 99$ for yield effects due to the irrigation treatment. The relationship between yield and water application for treatments 3 and 4 was consistent over the 4 years and the difference in yield was significant. On the average for the season, treatment 3 used 17.3% less water than treatment 4, but the yield for treatment 3 was 21.5% less than treatment 4. The ratio of 21.5% to 17.3% produces a yield response factor, K_y, of 1.24, which is much higher than the $K_y = 0.85$ given by Doorenbos and Kassam (1979) and the $K_y = 0.92$ given by Dagdelen et al. (2006). Using the spline function, there is a slight curvature near treatment 4 so that a 5% reduction in water application produces only a 4.6% reduction in yield. In either case the economics of using any water application less than used in treatment 4 points to the value of the crop loss being much higher than the reduction in cost of water for price conditions typical to this region. Treatment 4 produced the highest water use efficiency, as seen in Table 3. Any application higher than that used for treatment 4 did not significantly increase yield, so treatment 4 becomes a critical treatment. The peak effective water use efficiency of 0.219 kg/m^3 shown in Table 3 is well within the range for cotton given by Zwart and Bastiaanssen (2004) of 0.14–0.33 kg/m^3. The lack of any yield differences between varieties under various moisture regimes was also noted by Husman et al. (1999). With four levels of soil moisture

Table 3 – Depths of water application for season (mm), average lint yields (kg/ha), and water use efficiency (kg/m^3)

Year	Treatment number						Kern County yield (kg/ha)
	1	2	3	4	5	6	
2002	327	408	583	732	848	880	1564
2003	291	396	499	596	697	772	1494
2004	305	407	525	625	723	813	1686
2006	332	444	556	663	777	887	1464[a]
Average	314	414	541	654	761	838	
Combined average yield of two varieties (kg/ha)	412	719	1122	1433	1484	1461	
Effective water use efficiency (kg/m^3)	0.131	0.174	0.207	0.219	0.195	0.174	

The change in soil moisture status from before planting to after harvest is included.
[a] Estimate.

Table 4 – Ratio of depth of water applied to reference ET, for treatment 4 during mid-season when C_n = 1.0

Year	I/E_{pan} [a]	I/ET_0 [b]
2002	1.006	1.209
2003	0.987	1.284
2004	0.894	1.106
2006	0.918	1.078
Average	0.951	1.169

[a] I = depth of water applied; E_{pan} = pan evaporation.
[b] ET_0 = reference ET from CIMIS (California Irrigation Management Information System, Craddock, 1990).

depletion, they found no significant difference in yield between four varieties of cotton. Yields were consistently higher with the least depletion.

The potential ET in 2004, as shown in Table 1, was higher than average, so the ratio of water application to actual ET that year, shown in Table 4 for treatment 4, was low. This low water application could explain the lack of any levelling-off of the water production function in the wetter treatments that year. On the average, the depth of water application for treatment 4 during mid-season was 95.1% of the pan evaporation and 116.9% of the reference ET from the California Irrigation Management System (CIMIS) which is described in Snyder and Pruitt (1992) and also in Craddock (1990). This critical level amounts to 7.5 mm/day (0.951 × 7.86 mm/day) for a typical day in July. The water application rate for treatment 4 is also not greatly different from the maximum value for the crop coefficient of 1.15 found by Karam et al. (2006) for the time period just before the bolls start to form.

3.4. Soil moisture

The soil at planting time is near field capacity, which is about 13% by volume. At the end of the season the plants dry out the soil to a field wilting point of about 5%. Fig. 3a shows an example of how the moisture in the soil varied throughout the season. When water is applied at about the same rate that it is being used, as in treatment 4, the soil moisture stays almost constant. The wetter treatments caused the soil moisture to increase during the season, and the soil in the drier treatments dried out rapidly. Fig. 3b shows the average soil moisture for all 4 years. The soil moisture for treatment 4 is given for each year in Table 5. The average rate of decline in moisture for each year was determined by simple linear regression of the moisture data over time, and the slope is given in the table. A negative slope indicates deficit irrigation. The degree of deficit irrigation was determined by dividing the average daily loss by the normal mid-season daily water use of 7.1 mm/day from DeTar (2004) and is given as percent deficit in Table 5. In 2002 the water application for treatment 4 was 4.6% less than needed, a deficit level that cannot be considered excessive since treatment 4 that year produced the highest yields. This deficit occurred in spite of a water application rate that was the highest of the 4 years. One of the indicative properties of the yield decline over years (DeTar et al., 1994) is seen in the increase in the average soil moisture for treatment 4 in 2004. In spite of the lower than average water application ratio that year, the soil profile got wetter. The deficits and application ratios for 2003 and 2006 seem more normal in that where the application ratio was slightly higher than average, as in 2003, the soil got wetter, and where

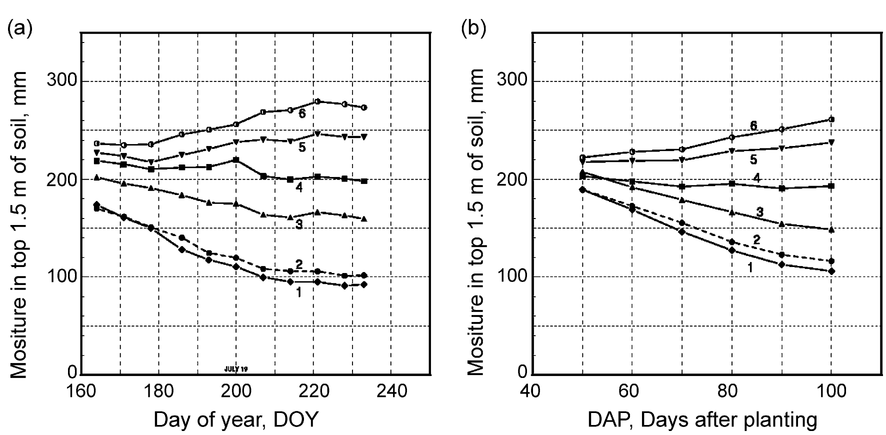

Fig. 3 – Soil moisture regimes: (a) an example of total profile moisture plotted vs. DOY for the year 2006; (b) the 4-year average for total profile moisture, plotted against days after planting (DAP). Treatment numbers are shown in the figure.

Table 5 – Moisture in top 1.5 m of soil for treatment 4 (mm)

Year	Days after planting (DAP)						Slope (mm/day)	Deficit (%)
	50	60	70	80	90	100		
2002	216	216	199	195	172	179	−0.919	4.6
2003	190	180	171	176	183	187	0.004	−0.02
2004	190	185	188	194	205	206	0.411	−2.1
2006	218	211	212	217	203	201	−0.291	1.5
Average	203	198	192	196	191	193	−0.199	1.0

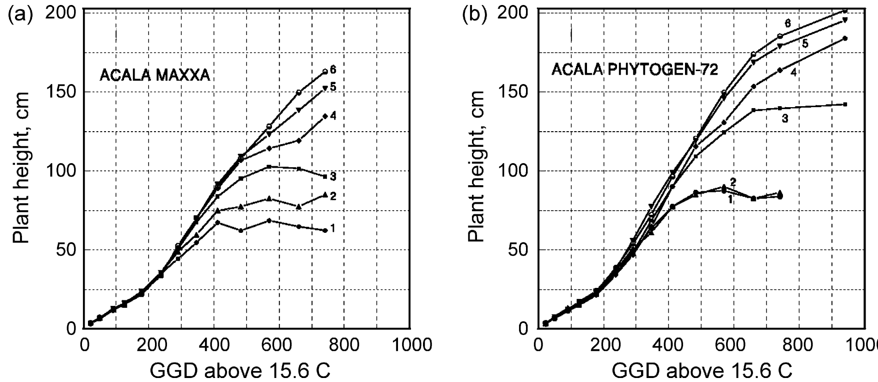

Fig. 4 – Height of Acala cotton plants as a function of growing-degree-days during 2002: (a) Maxxa; (b) PhytoGen-72. Treatment numbers are shown in the figure.

the application ratio was below average there was a deficit (2006).

3.5. *Plant height and length of season*

One of the more important results of the six irrigation treatments is the effect on plant height. Fig. 4 provides examples of how the plant height was affected by the treatments throughout the season, when plotted vs. growing-degree-days (GDD) above 15.6 °C accumulated from day of planting. In 2002 the PhytoGen-72 plants in treatment 6 had a final height of 202 cm, and by contrast they reached only 84 cm in treatment 1. For Maxxa in 2002, the final height was 163 cm and 62 cm for treatments 6 and 1, respectively. The first year back into cotton following a rotational crop or fallow is sometimes characterized by lush growth (DeTar, 2004). Table 6 shows the final plant heights for each treatment for all 4 years and shows how the plants were much taller in 2002 than in the following years, especially in the wetter treatments. Also one notes that the PhytoGen-72 plants were consistently taller than Maxxa plants, with an average difference of 35 cm for treatment 4. PhytoGen-72 plants are well known to produce more main stem nodes than Maxxa, and thus more fruiting positions and more yield potential. The height of the plants within a variety is clearly dependent on the water application. By comparing the early-season heights one notices very little difference in the rate of growth before cutout (cessation of main stem node production). The large differences in final height are largely due to when cutout occurred, the drier treatments cutting out much earlier than the wettest treatments. The day of year (DOY) at which cutout occurs is plotted against the treatment factor, F_t, in Fig. 5 for 2003. Cutout on treatment 1 occurred 31 days earlier than in treatment 6 for PhytoGen-72 in 2003. As indicated by the parallel regression lines in Fig. 5, Maxxa displayed a similar relationship, but cutout was about 7 days earlier than it was for the PhytoGen-72. Table 7 gives the DOY for cutout for all treatments for the 4 years and show that the relationship between the two varieties is not always parallel. On the average for the 4 years, the PhytoGen-72 cutout 10.3 days later than Maxxa for treatment 4. The difference in the DOY for cutout between treatment 1 and treatment 6 tended to decline over the years and averaged 33 days for PhytoGen-72 and only 16 days for the Maxxa; over-watering PhytoGen-72 can cause considerable delay in cutout.

Table 6 – Final plant height for Acala cotton (cm)

Variety	Year	Treatment numbers					
		1	2	3	4	5	6
Maxxa	2002	62	85	97	135	152	163
Maxxa	2003	66	71	97	94	133	122
Maxxa	2004	57	74	79	80	97	97
Maxxa	2006	67	71	86	118	108	101
PhytoGen-72	2002	84	86	142	184	196	202
PhytoGen-72	2003	58	84	90	130	164	177
PhytoGen-72	2004	67	97	109	127	139	165
PhytoGen-72	2006	58	78	99	126	142	158

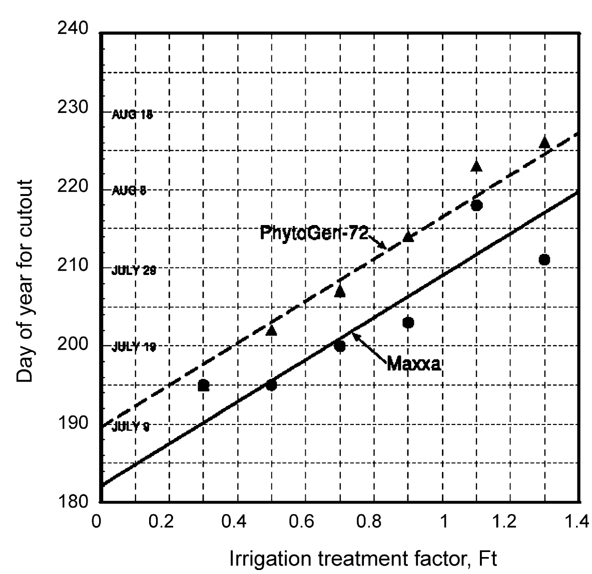

Fig. 5 – Day of year for cutout as a function of the treatment factor in 2003.

Table 7 – Day of year (DOY) for cutout in Acala cotton based on five nodes above white flower (NAWF)

Variety	Year	Treatment numbers					
		1	2	3	4	5	6
Maxxa	2002	184	190	198	203	202	214
Maxxa	2003	195	195	200	203	218	211
Maxxa	2004	191	193	194	198	197	205
Maxxa	2006	185	186	191	192	190	190
PhytoGen-72	2002	191	197	215	218	230	233
PhytoGen-72	2003	195	202	207	214	223	226
PhytoGen-72	2004	191	197	206	211	215	224
PhytoGen-72	2006	187	190	195	204	210	213

Table 8 – Day of year (DOY) Acala cotton was ready to defoliate, based on six nodes above cracked boll (NACB)

Variety	Year	Treatment numbers					
		1	2	3	4	5	6
Maxxa	2002	247	247	259	259	280	275
Maxxa	2003	243	243	251	258	269	266
Maxxa	2004	244	246	249	251	265	268
Maxxa	2006	236	236	245	256	257	255
PhytoGen-72	2002	247	247	259	263	280	280
PhytoGen-72	2003	240	243	251	258	265	269
PhytoGen-72	2004	244	249	251	254	254	271
PhytoGen-72	2006	232	236	244	248	258	260

Another measurement that shows how moisture regime affects the length of season is seen in Fig. 6 where the DOY when the plants are ready to defoliate (six nodes above cracked boll) is plotted against the treatment factor, F_t. This DOY marks the end of the growing season. It is important to note here that even though PhytoGen-72 cutout a week later than Maxxa in 2003, they were both ready to defoliate at about the same time, indicating that the PhytoGen-72 matured much faster than Maxxa after cutout; this same effect was apparent in all four seasons. Treatment 1 was ready to defoliate 26 days earlier than treatment 6 for the average of the two varieties in 2003. The average for all 4 years is about the same, as can be seen in Table 8. As with cutout, this difference in the DOY for the end of the season tended to decline over the years. The DOY when the plants were ready to defoliate for Maxxa was essentially the same as for PhytoGen-72 every year. Bhattarai et al. (2006) found in a similar manner that applying just half the required water shortened the season by 25 days. Both plant height and the length of season can be controlled by the amount of water applied.

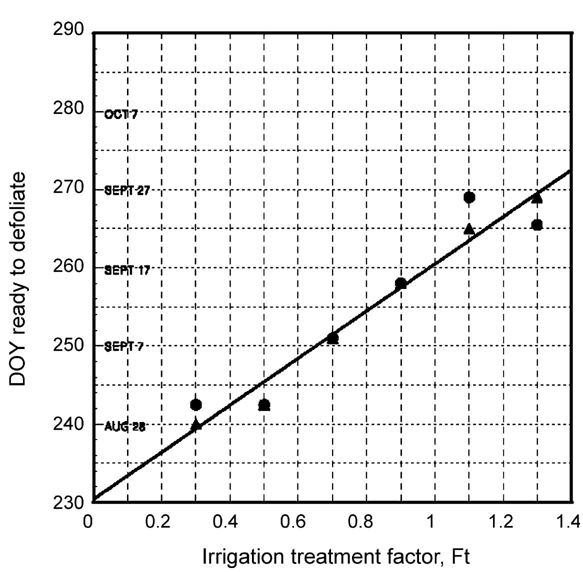

Fig. 6 – Day of year ready to defoliate as a function of the treatment factor in 2003. Triangles are PhytoGen-72 and circles are Maxxa.

4. Conclusions

There was no significant difference in yield between the two varieties, nor was there any significant difference among the three wettest treatments. The optimum water application regime, treatment 4, was one that kept the soil moisture nearly constant throughout the season. Over four seasons treatment 4 had a mid-season application rate that averaged 95% of pan evaporation and 117% of the CIMIS ET. The total depth of water applied for the season for this treatment averaged 654 mm of water. It represented the least amount of water applied that still produced essentially maximum yield, and it had the highest effective water use efficiency. Any application rate less than treatment 4 reduced yields sharply. From the water production function curve, reducing the application rate by 5% below the treatment 4 level would decrease the yield by 4.6%. It is recommended, therefore, that deficit irrigation be avoided for similar climate and soil conditions.

We documented the degree to which the water application rate controlled the plant height and length of season. The final plant heights were closely related to the depth of water applied and varied from 0.6 m to 2.0 m. At the extremes of water application rates, there were some slight differences in early-season growth rates of the plants, but the main cause for the differences in final height of the plants was the date of cutout. The cotton in the driest treatment cutout about a month earlier than in the wettest treatment; on the average it was 33 days earlier with Acala PhytoGen-72 and 23.5 days earlier with Acala Maxxa. For treatment 4, PhytoGen-72 cutout 10.3 days later than Maxxa, but by harvest time, there was no difference. On the average, the end of the season for both varieties came 26 days earlier on the driest treatment than on the wettest treatment.

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